Transition from direct to inverse cascade in 3D Turbulence

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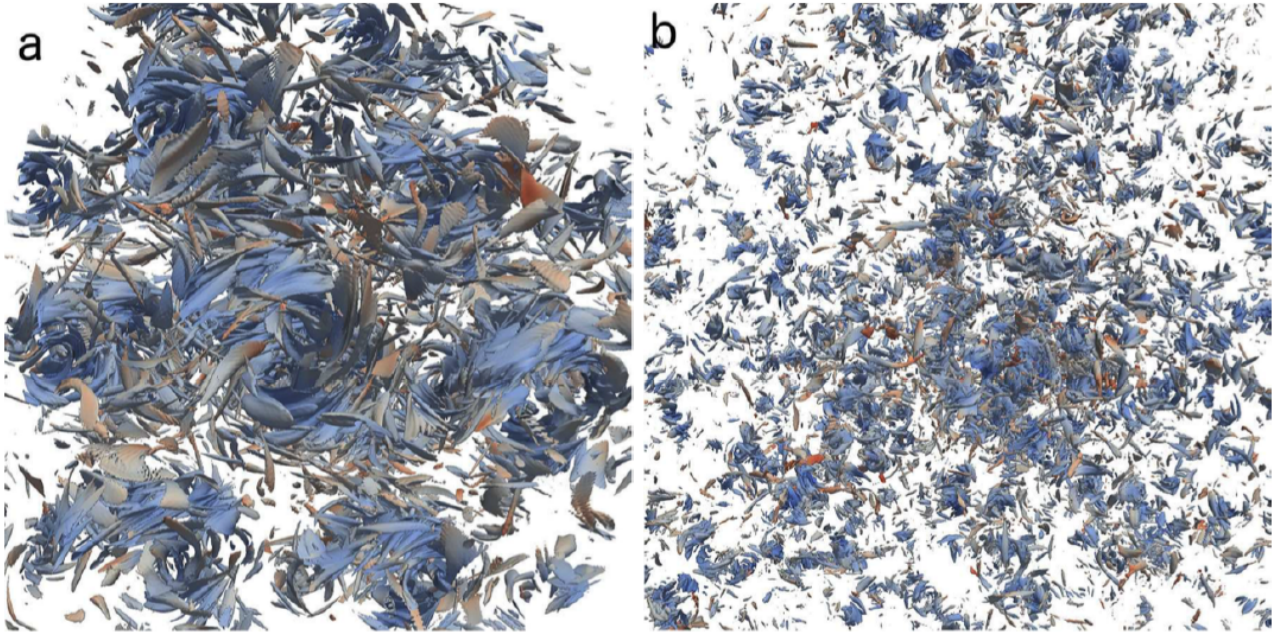

with **G. Sahoo** (U. Tor Vergata, Italy & U. Helsinki, Finland), **A. Alexakis (**ENS, Paris, France)

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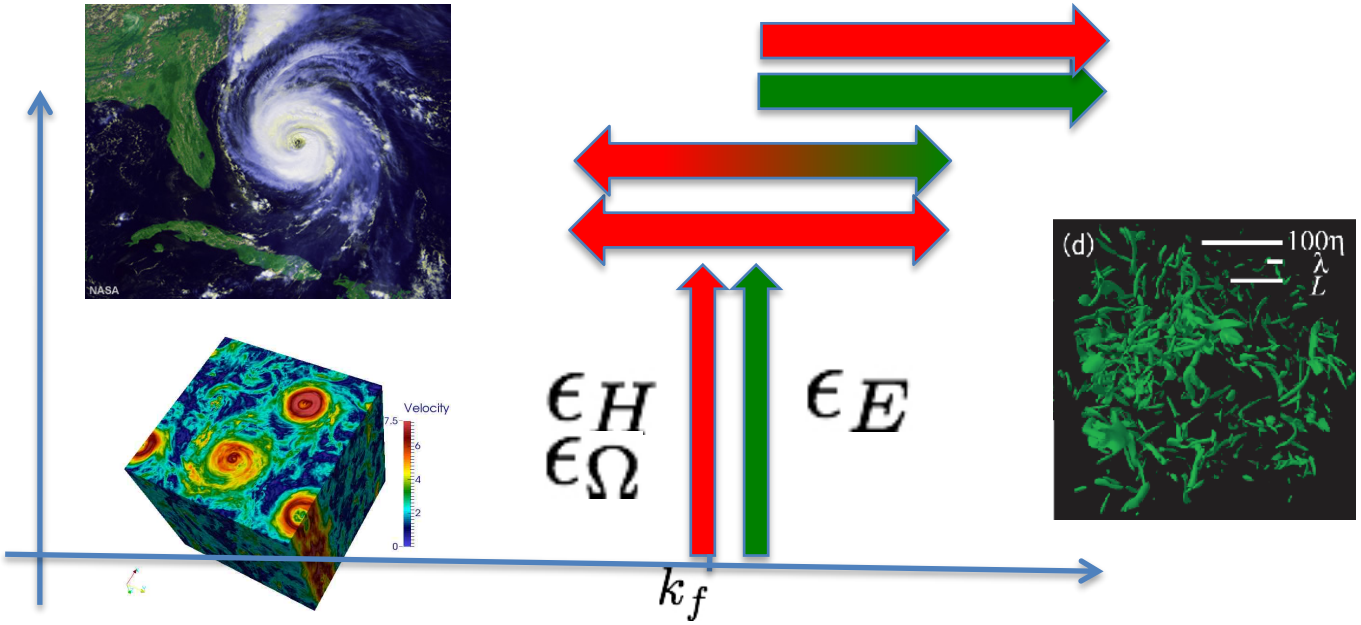
MOTIVATIONS:

A TALE ABOUT TRANSFER PROPERTIES OF INVISCID CONSERVED QUANTITIES, KINETIC ENERGY, HELICITY ENSTROPHY, MAGNETIC HELICITY ETC…

Q1: HOW TO PREDICT THE DIRECTION OF THE TRANSFER (FORWARD/BACKWARD) AND ITS ROBUSTNESS UNDER EXTERNAL PERTURBATION (FORCING/BOUNDARY CONDITIONS)?

Q2: HOW MUCH THE FLUCTUATIONS AROUND THE MEAN TRANSFER ARE INTENSE AND SELF-SIMILAR (INTERMITTENCY AND ANOMALOUS SCALING) ?

AS A MATTER OF FACT, FOR 3D NAVIER STOKES EQUATIONS, WE DO NOT KNOW HOW TO PREDICT NEITHER THE SIGN OF THE MEAN ENERGY TRANSFER NOR THE INTENSITY OF THE FLUCTUATIONS AROUND IT.



Q: CAN WE DISSECT 3D NS EQUATIONS TO EXTRACT INTERESTING INFORMATION FROM ITS ELEMENTARY CONSTITUENTS?

R: PLAY WITH MIRROR SYMMETRY

$$\begin{cases} \partial_t \mathbf{v} + (\mathbf{v}\cdot\partial)\mathbf{v} = -\partial P + \nu\Delta\mathbf{v} + \mathbf{F} \\ \partial\cdot\mathbf{v} = 0 \\ + \textit{Boundary Conditions} \end{cases}$$

Piero della Francesca ~ 1450 C.E. Monterchi IT

Commun. Math. Phys. 115, 435–456 (1988)

The Beltrami Spectrum for Incompressible Fluid Flows

Peter Constantin[1,⋆] and Andrew Majda[2,⋆⋆]

The nature of triad interactions in homogeneous turbulence

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(Received 24 July 1991; accepted 22 October 1991)

$$\boldsymbol{u}(\boldsymbol{k}) = u^+(\boldsymbol{k})\boldsymbol{h}^+(\boldsymbol{k}) + u^-(\boldsymbol{k})\boldsymbol{h}^-(\boldsymbol{k})$$

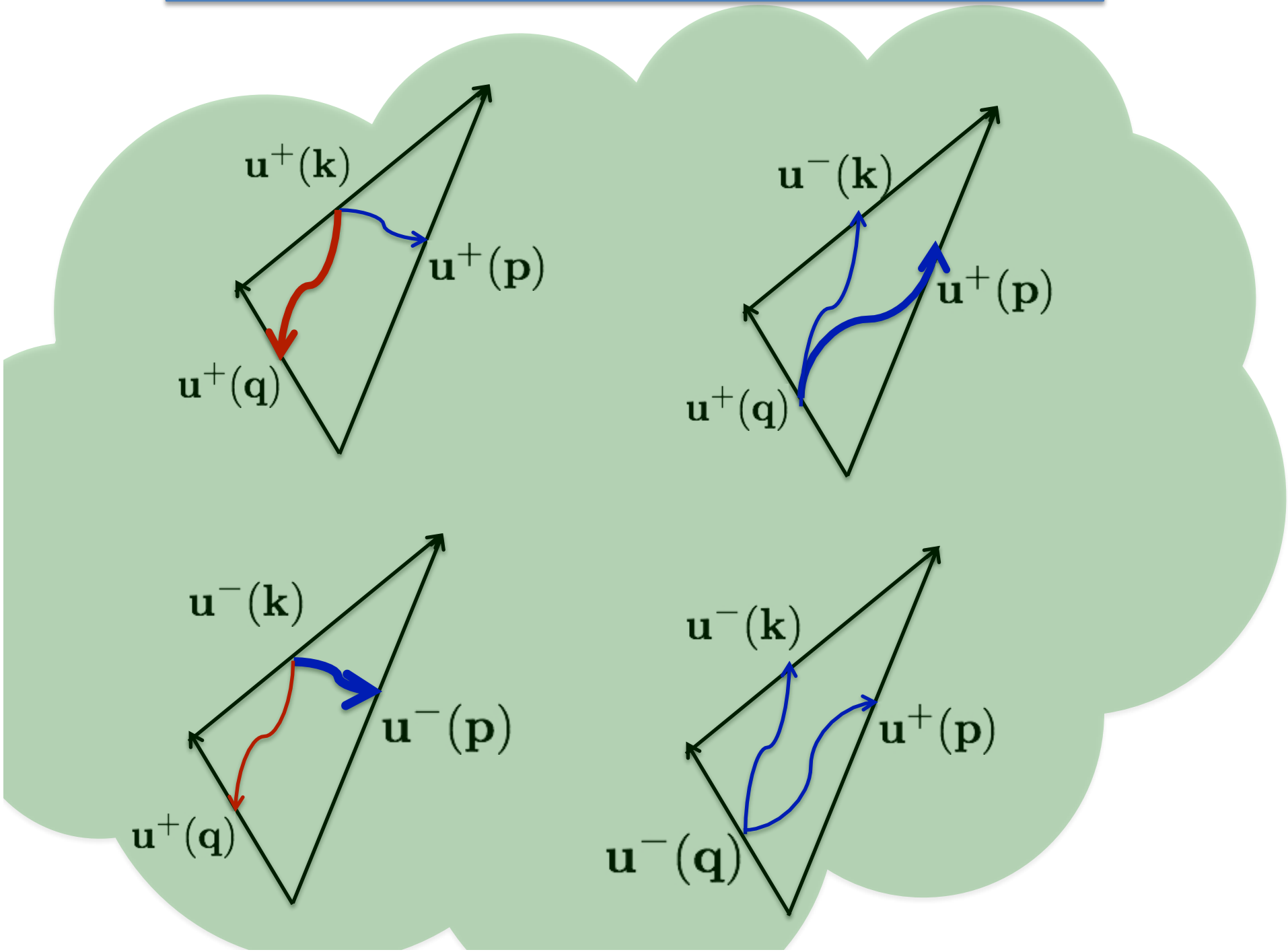
$$\boldsymbol{h}^\pm = \hat{\boldsymbol{\nu}} \times \hat{\boldsymbol{k}} \pm i\hat{\boldsymbol{\nu}}$$

$$\hat{\boldsymbol{\nu}} = \boldsymbol{z} \times \boldsymbol{k}/||\boldsymbol{z} \times \boldsymbol{k}||$$

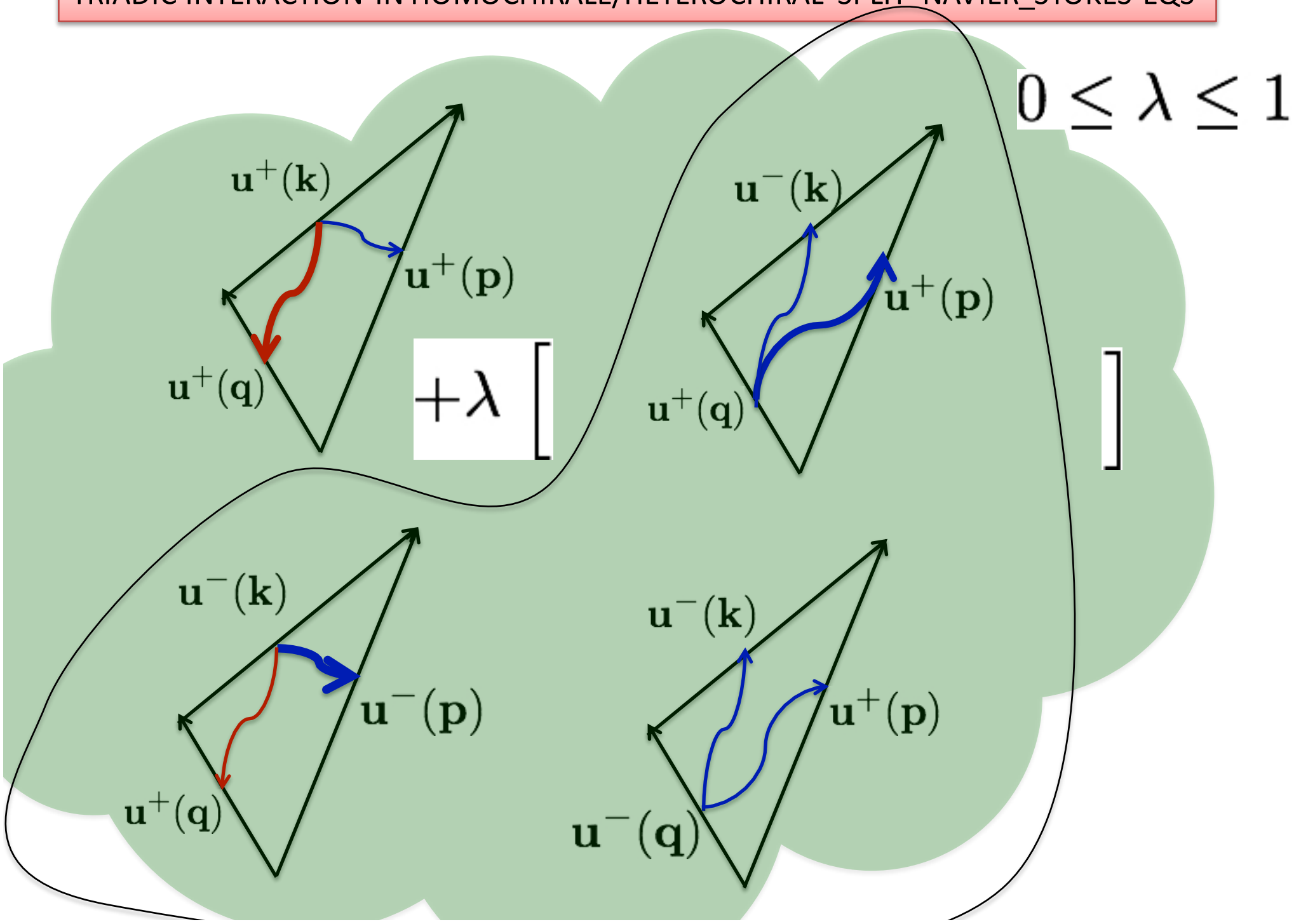
$$i\boldsymbol{k} \times \boldsymbol{h}^\pm = \pm k\boldsymbol{h}^\pm$$

$$\begin{cases} E = \sum_{\boldsymbol{k}} |u^+(\boldsymbol{k})|^2 + |u^-(\boldsymbol{k})|^2; \\ H = \sum_{\boldsymbol{k}} k(|u^+(\boldsymbol{k})|^2 - |u^-(\boldsymbol{k})|^2). \end{cases}$$

HELICAL-FOURIER TRIADIC INTERACTION IN NAVIER_STOKES EQS



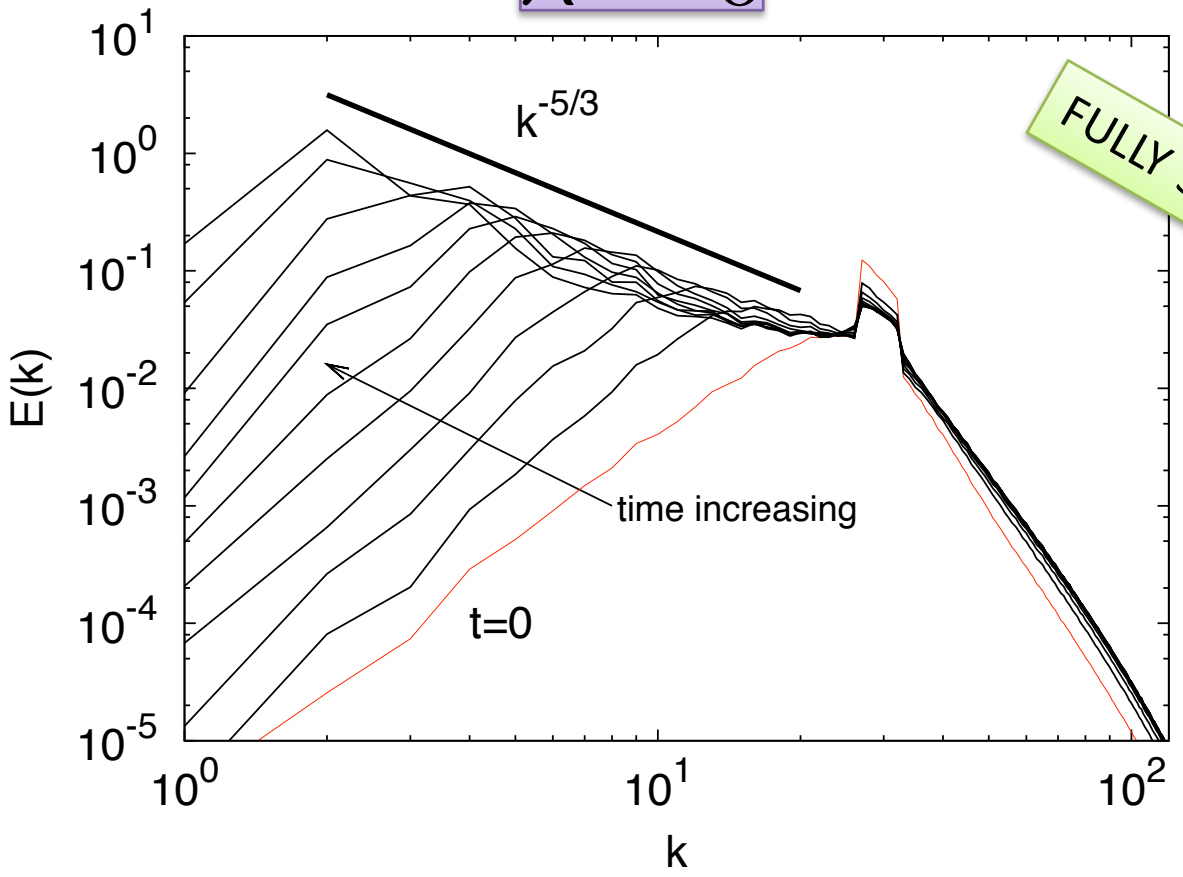
TRIADIC INTERACTION IN HOMOCHIRALE/HETEROCHIRAL SPLIT_NAVIER_STOKES EQS



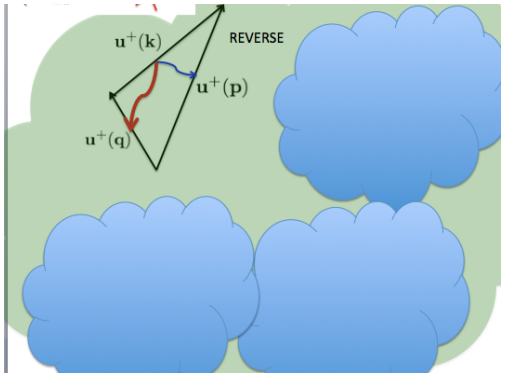
HOMOCHIRAL 3D NAVIER STOKES EQS.

$$\begin{cases} E = \sum_{\boldsymbol{k}} |u^+(\boldsymbol{k})|^2 + |u^-(\boldsymbol{k})|^2; \\ H = \sum_{\boldsymbol{k}} k(|u^+(\boldsymbol{k})|^2 - |u^-(\boldsymbol{k})|^2). \end{cases}$$

$$\lambda = 0$$



FULLY 3D AND ISOTORPIC

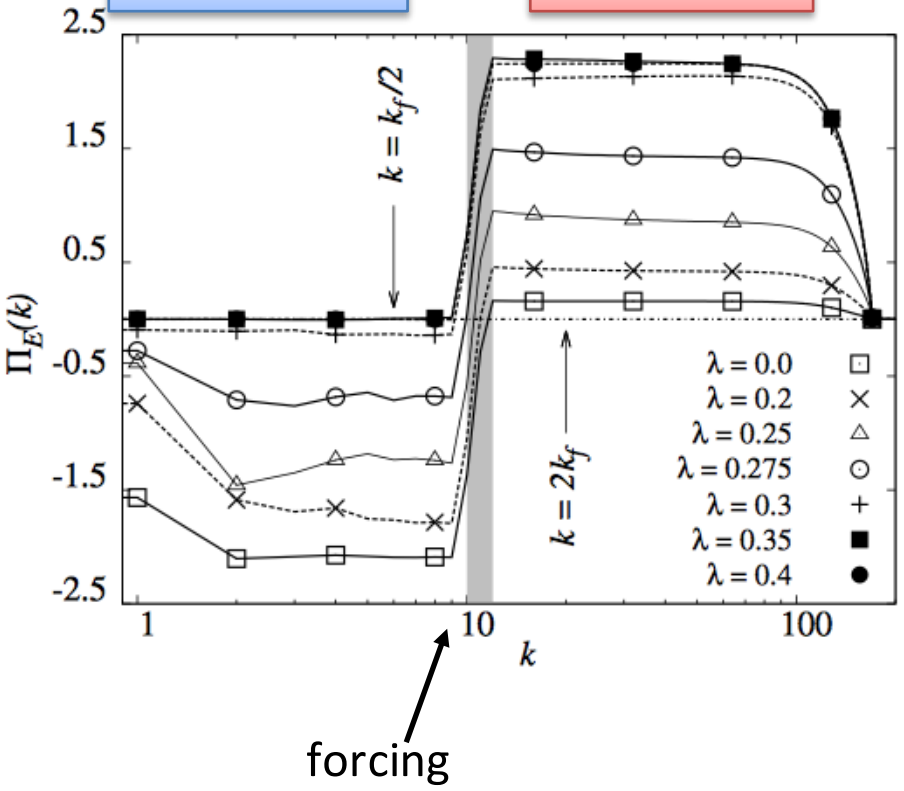


L.B., S. MUSACCHIO & F. TOSCHI Phys. Rev. Lett. 108 164501, 2012.

ENERGY FLUX

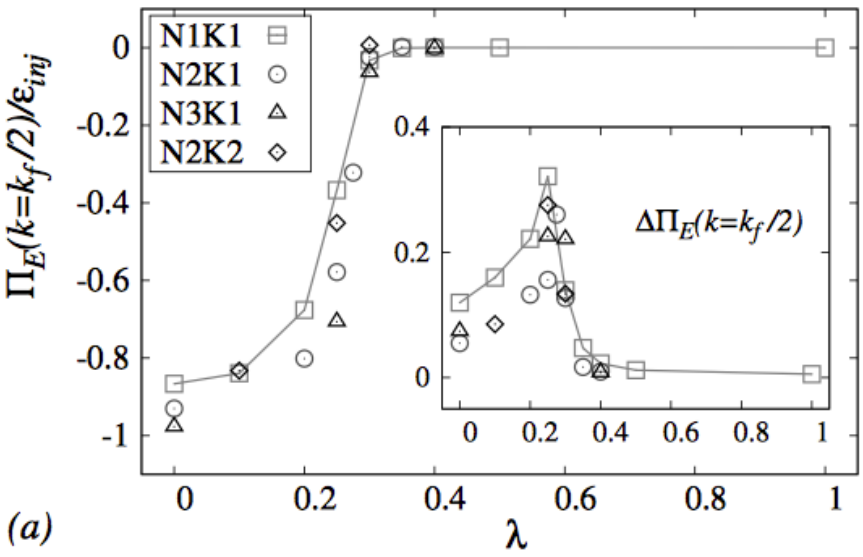
INVERSE CASCADE

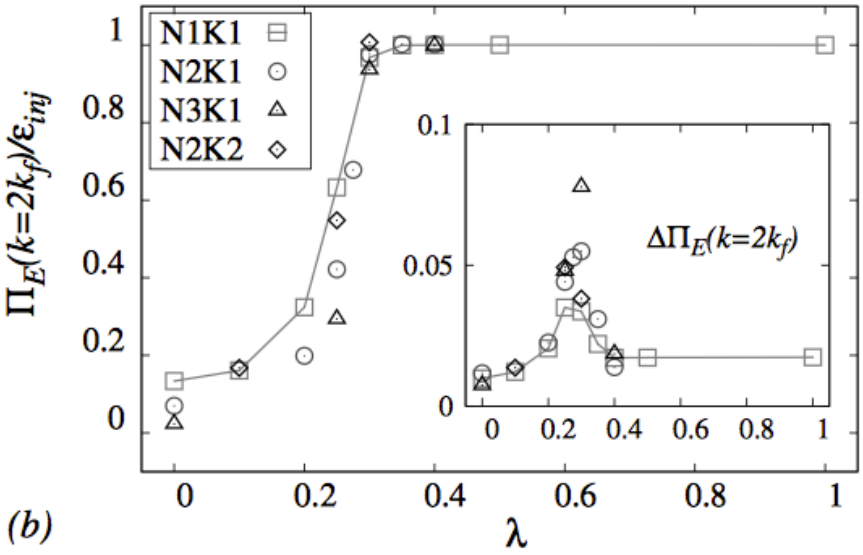
DIRECT CASCADE



INVERSE CASCADE

DIRECT CASCADE





ALL THREE DIMENSIONAL FLOWS IN NATURE POSSES FOURIER-INTERACTIONS ABLE TO TRANSFER ENERGY EITHER BACKWARD (HOMOCHIRAL TRIADS) OR FORWARD (HETEROCHIRAL)

IN NATURAL CONDITIONS THE HETEROCHIRAL TRIADS ARE MORE EFFICIENT AND ENERGY CASCADES FORWARD IN HOMOGENEOUS AND ISOTROPIC TURBULENCE

IF HETEROCHIRAL TRIADS ARE LESS EFFICIENT, A SHARP REVERSE OF THE ENERGY CASCADE IS OBSERVED **WITHOUT BREAKING OF ANY SYMMETRY**

Discontinuous Transition from Direct to Inverse Cascade in Three-Dimensional Turbulence
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Role of helicity for large-and small-scales turbulent fluctuations
G Sahoo, F Bonaccorso, and L Biferale.
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L Biferale, S Musacchio, and F Toschi.
Phys. Rev. Lett. 108, 164501 (2012).